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Two new species of *Periophthalmus* (Teleostei: Gobiidae: Oxudercinae) from northern Australia, and a re-diagnosis of *Periophthalmus novaeguineaensis*

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ABSTRACT

Two new species of mudskipper (genus *Periophthalmus*) are described from mangrove habitats of north-western Australia. They both resemble small specimens of *Periophthalmus novaeguineaensis* Eggert, 1935, and have been confused with that species. *Periophthalmus darwini* n. sp. is distinguished by a combination of characters, in particular a greatly reduced first dorsal fin in both sexes. *Periophthalmus murdyi* n. sp. is distinguished by a combination of characters, including heavily pigmented pelvic fins and a relatively plain blackish first dorsal fin. *Periophthalmus novaeguineaensis* is re-diagnosed, as the data presented in its 1989 review by Murdy was found to include that of the two new species. *Periophthalmus expeditionium* Whitley, 1953, may be a valid species also. A dichotomous key to all *Periophthalmus* species is included.

KEYWORDS: *Periophthalmus*, *Periophthalmus novaeguineaensis*, *Periophthalmus expeditionium*, Gobiidae, Oxudercinae, northern Australia, new species, mudskipper.

INTRODUCTION

Mudskippers of the genus *Periophthalmus* occur throughout the Indo-Pacific, with a single species in west Africa. These are gobiid fishes currently placed in the subfamily Oxudercinae (there is some nomenclatural controversy over the subfamily name that will not be dealt with here), and 15 species of *Periophthalmus* are presently recognised (Murdy 1989; Lee *et al.* 1995; Murdy and Takita 1999; Darumas and Tantichodok 2002). However, a number of specimens exist that do not quite agree with species described in these papers, and that sit mislabelled in museum collections.

During ecological studies on the mudskippers of mudflats and mangroves in the Northern Territory (NT) and Western Australia (WA), the junior author identified two species of mudskipper that appeared to be new. Subsequent examination of specimens in the collection of the Museum and Art Gallery of the Northern Territory (NTM) revealed additional specimens of these new species, most of which had been previously identified as *Periophthalmus novaeguineaensis*. Indeed, a number of the specimens reported as *P. novaeguineaensis* by Murdy (1989) are the new species (e.g. NTM S.10554-001 and NTM S.11360-015 are *P. darwini* n. sp., and NTM S. 10426-002 is *P. murdyi* n. sp.). Because Murdy's data and diagnosis of *P. novaeguineaensis* thus includes three species, it became necessary to examine relevant type specimens and redescribe the species.

METHODS AND MATERIALS

Methods of measuring specimens are generally those as used by Murdy (1989), using electronic callipers, with several differences. Measurements of first dorsal fin base, and distance between dorsal fins, both include the membrane that joins the last ray to the dorsal surface of the body (no such membrane exists at the posterior part of the second dorsal or anal fin), and body depth is taken twice, at the anal fin origin (BDA) and at the origin of the pelvic fin base. Pectoral fin length does not include the fin base. Fish lengths are standard length (SL).

Counts of second dorsal and anal fin rays distinguish between unsegmented and segmented rays, unlike Murdy (1989). Lateral scale counts do not include scales on the caudal fin; counts end at the hypural crease. Transverse scale counts backward (TRB) are taken at the origin of the anal fin dorsoposteriorly to second dorsal fin base. Transverse scale counts forward (TRF) are taken at the origin of the anal fin anterodorsally to first dorsal fin base (or last scale before dorsal midline, depending on position of first

dorsal fin). Dorsal pterygiophore counts are presented as in Birdsong *et al.* (1998).

Institutional abbreviations follow Leviton *et al.* (1985).

In the descriptions below, counts and measurements for holotype are given first, with the range for paratypes in parentheses.

SYSTEMATICS

Family Gobiidae Cuvier

Subfamily Oxudercinae Günther

Periophthalmus Bloch and Schneider

Periophthalmus darwini new species

(Figs 1, 2, 7A,B; Tables 1, 2)

Periophthalmus novaeguineaensis [in part] – Murdy 1989: 42.

Type material. HOLOTYPE – NTM S.10554-004, 45.5 mm male, mud banks at Mickett Creek, Shoal Bay, NT, HL 82-39, H.K. Larson, P. Horner and P. Davie, 30 June 1982. PARATYPES – NTM S.10554-001, 47(22–45), same data as holotype; NTM S.11360-015, 7(28–40), *Sonneratia* mangrove at Darbilla Creek, just south of Milingimbi settlement, NT, HL 84-25, H.K. Larson, P. Horner, B. Johannes and Lyle, 23 July 1984; NTM S.14400-006, 3(32.5–39.5), mangrove on beach south of Pickertaramoor, Melville Island, NT, HL 96-19, H.K. Larson and M. Mahoney, 13 October 1996; NTM S.10694-022, 14(30–34), mangrove creek to right of camp-ground, Gunn Point, NT, HL 82-52, H.K. Larson and R.S. Williams, 20 September 1982; NTM S.15801-001, 8(36.5–42.5), mudflats west of abandoned prawn farm ponds at tip of Howard Peninsula, Hope Inlet, NT, T. Takita, 27 July 2001; AMS I.43230-001, 7(32.5–43), same data as previous; NSMT-P 67977, 5(33–40.5), same data as previous.

Diagnosis. A slender-bodied *Periophthalmus* (body depth at anal fin origin 10.6–14.6% of SL, mean 12.7%), unique among *Periophthalmus* species in having a greatly reduced first dorsal fin (depressed dorsal 5.1–9.6% of SL) in both sexes, and usually with only five spines, fin widely separated from second dorsal fin origin; pelvic fins united for half their length, distinct fraenum present, posterior tips of fins pointed to bluntly pointed, fifth ray bifurcating close to base and branching about 9 times; first dorsal fin plain blackish except for slightly paler base and narrow whitish margin; second dorsal fin translucent with broad submarginal black band and a row of black spots or blotches along fin base; no melanophores on anal fin; pelvic fins whitish or with some fine speckling; orange spots may be present on lower side of head and body when live; second dorsal fin rays modally I,11; anal fin rays modally I,12; pectoral rays 11–13; caudal fin rays usually only with ventralmost 6–7 rays branched, dorsalmost 8–9 rays rarely branched; lateral scales 58–78; predorsal scales usually 24–25.

Description. Based on 36 specimens, 23.5 to 45.5 mm SL.

First dorsal fin V (IV-VI); second dorsal fin I,11 (I,10-12); anal fin I,12 (I,11–13); pectoral rays 11 (11–14); caudal fin segmented rays in 8/7 pattern (8/7 to 9/8), with branched rays in 0/5 pattern (0/3 to 3/7); lateral scales 64 (58–78); TRB 15 (15–23); TRF 16 (16–23); predorsal scales 23 (20–30). Dorsal pterygiophore pattern 3-1301000 (in six specimens), 3-1301000 (in seven), 3-230100 (in one); usually 1 pre-anal pterygiophore (2 in one specimen, 13 with 1); usually 2 epurals (1 in one specimen, 13 with 2) (Table 1).

Body slender, BDA 10.6%–14.6% of SL; adult size small (up to 45.5 mm SL) (Fig. 1). Head length 24.6–29.5% of SL; head width slightly greater than

Table 1. Counts and measurements of specimens of *Periophthalmus darwini* n. sp.

	Holo.	Mean	Max.	Min.	Mode
First dorsal fin spines	5.0	4.9	6.0	4.0	5.0
Second dorsal fin rays	11.0	10.9	12.0	10.0	11.0
Anal fin rays	12.0	12.4	13.0	11.0	12.0
Pectoral rays right	11.0	11.5	13.0	11.0	11.0
Pectoral rays left	11.0	11.9	14.0	11.0	12.0
Caudal segmented	15.0	15.2	17.0	15.0	15.0
Caudal branched	5.0	6.6	10.0	3.0	7.0
Lateral scales	64.0	69.2	78.0	58.0	67.0
Transverse rows back	15.0	18.3	23.0	15.0	19.0
Transverse rows forward	16.0	19.5	23.0	16.0	21.0
Predorsal scales	23.0	24.4	30.0	20.0	25.0
Standard length	45.5	36.5	45.5	23.5	37.0
Head length	12.8	9.9	12.8	6.3	11.2
Head width	7.7	6.1	7.7	4.1	6.0
Head depth	8.2	6.4	8.2	4.1	6.5
Body depth at anal base	6.1	4.6	6.1	2.5	4.6
Body depth at pelvic base	7.8	6.0	7.8	3.8	5.8
Length before D1	16.8	13.0	16.8	1.2	13.2
D1 base length	3.9	2.9	4.0	1.7	3.0
Distance between dorsals	7.6	6.4	8.1	4.0	7.2
D2 base length	8.0	6.9	8.5	4.0	8.2
Length behind D2	9.5	7.4	9.5	4.8	7.8
Anal base length	9.0	7.6	9.0	4.8	7.0
Caudal peduncle length	9.2	7.2	9.2	4.8	7.0
Caudal peduncle depth	4.0	3.1	4.0	1.9	3.0
Depressed D1	3.9	3.0	3.9	1.8	3.3
Pectoral base height	3.0	2.2	3.5	1.4	2.1
Pectoral length	8.5	6.4	8.5	4.1	6.8
Pelvic length	6.0	4.5	6.0	2.7	4.4
Caudal length	10.0	8.2	10.0	4.8	8.8
First D1 spine	2.3	2.1	2.7	1.4	2.3
Second D1 spine	2.4	2.1	2.6	1.3	1.8
Third D1 spine	-	2.1	2.1	2.1	-

Fig. 1. Holotype of *Periophthalmus darwini* n. sp., NTM S.10554-001, 45.5 mm SL male, Shoal Bay, NT. Photograph by T. Takita.

head depth. First dorsal fin greatly reduced in both sexes, triangular in shape with first dorsal spine often longest, fin widely separated from second dorsal fin, gap between dorsal fins 15.2–20.0% of SL. Second dorsal and anal fins very low and short, distance between posteriomost second dorsal fin ray and caudal fin base 18.5–23.0% of SL (Table 2). Pelvic fins with distinct frenum, fins united for about half their length; fifth pelvic fin ray short, branching about nine times, branches commencing close to base of ray, with unbranched portion covered by muscle tissue.

Females with short blunt slightly cylindrical genital papilla; papilla in males usually flattened and pointed, usually somewhat elongate.

Coloration of preserved material. Head and body light brown to greyish brown, underside of body whitish to yellowish (unpigmented), underside of head may have scattered brownish pigment on isthmus and chin. About nine forwardly-oblique, narrow, dark brown bars across dorsum: first two cross predorsal region, third bar at origin of first dorsal fin, fourth bar midway in gap between dorsals, fifth at second dorsal fin origin, sixth bar at centre of second dorsal, seventh at rear of second dorsal fin, eighth on caudal peduncle just before dorsal procurrent rays and a ninth on midbase of caudal fin; dark brown mottling, spots or blotches may be present between each oblique bar; all dark brown bars end near mid-side of body. Head with small brown spots, oblique streaks and mottling.

Table 2. Morphometrics of specimens of *Periophthalmus darwini* n. sp., expressed as percentage of standard length (SL) or head length (HL).

	Holo.	Mean	Max.	Min.
HL in SL	28.1	27.3	29.5	24.6
HD in HL	60.2	61.3	68.8	57.8
HW in HL	64.1	64.2	71.3	58.4
BD at A base in SL	13.4	12.7	14.6	10.6
BD at P2 base in SL	17.1	16.5	17.6	15.5
Length anterior to D1 in SL	36.9	35.6	38.9	3.5
D1 base length in SL	8.6	8.0	9.8	5.3
Distance between dorsal fins in SL	16.7	17.7	20.0	15.2
D2 base in SL	17.6	19.0	22.1	16.8
Distance from D2 last ray to caudal in SL	19.8	20.7	23.0	18.5
A base in SL	20.2	20.1	22.6	17.7
CPL in SL	8.8	10.8	22.2	7.9
CPD in SL	8.6	8.3	9.6	7.0
Depressed D1 in SL	6.6	6.6	9.6	5.1
Pectoral base in SL	8.6	14.9	19.4	5.4
Pectoral in SL	6.6	13.3	19.2	6.6
Pelvic in SL	18.7	20.4	25.4	11.8
Caudal in SL	13.2	9.6	24.1	4.9
First D1 spine in SL	22.0	6.1	22.0	4.4
Second D1 spine in SL	22.0	6.2	22.0	4.6
Third D1 spine in SL	5.1	5.4	5.8	5.1

First dorsal fin plain dusky, with whitish or translucent margin. Second dorsal fin translucent with two to three slightly oblique and irregular rows of elongate dusky spots, which may coalesce to form a line along centre of fin, margin whitish to transparent. Anal fin plain whitish. Caudal fin pale to dusky brown, with about seven rows of small brownish spots which may form irregular vertical rows (usually most pronounced near fin base), ventralmost quarter of fin plain dusky to whitish. Pectoral fin translucent with brown pigment following fin rays. Pelvic fins whitish ventrally, with some light brown speckling along fin rays on dorsal surface.

Coloration of fresh material. A live specimen is shown in Fig. 2. Field notes for several lots indicate that the live fish had bright orange spots on the head and body, similar to those in *P. novaeguineaensis* (which they were assumed to be at the time of collection).

Two living fish from Channel Island were a light brown to fawn colour on head and body, paling to dull whitish ventrally, with about 10 forwardly oblique narrow slightly darker brown to grey-brown bars and saddles from dorsal mid-line; side of head and body

Fig. 2. Live *Periophthalmus darwini* n. sp., near the mouth of the Howard River, NT. Photograph by T. Takita.

with pearly white to silvery whitish irregular patches and short vertical lines along side of body and lower half of head, interspersed with the oblique bars; first dorsal fin black, pale brown at base; second dorsal fin translucent to translucent fawn with basal row of irregular brown spots and sub-marginal brown band (broken-up); pectorals pinkish brown, pigment most developed along fin rays; pelvics plain pinkish brown on dorsal surface; anal fin plain dull whitish; caudal fin translucent light brown with 2–3 short oblique darker brown bars crossing anterordorsal portion of fin and 4–5 irregular oblique rows of brown spots crossing fin; eyes dark gold-flecked brown; underside of head whitish; lips pale brown.

Distribution. Northern Territory, from Melville Island; Darwin Harbour to Milingimbi; and Roebuck Bay, Western Australia. Melville Island specimens came from a small isolated mangrove behind a beach dune, with no connection to the sea (at that time). The ecology of this species will be discussed by Takita (in prep.).

Remarks. *Periophthalmus darwini* could possibly be confused with small female specimens of *P. weberi* Eggert, 1935, a species known from northern Australia and New Guinea (Murdy 1989). However, *P. weberi* has the pelvic fraenum reduced or lacking, and females have a reduced first dorsal fin represented only by a few spines (males have an enlarged fin that is contiguous with the second dorsal fin).

Of the specimens reported as *P. novaeguineaensis* by Murdy (1989), four lots were *P. darwini* (NTM S.10472-018, NTM S.10554-001, NTM S.11114-002, NTM S.11360-015) and two lots included some specimens of *P. darwini* (5 out of NTM S.10429-025, and 14 out of NTM S.10694-001).

Etymology. The species is named for the naturalist Charles Darwin, after whom Darwin Harbour (where the holotype was collected) was named.

Periophthalmus murdyi new species

(Figs 3–6, 7C,D, 8D–G; Tables 3, 4)

Periophthalmus novaeguineaensis [in part] – Murdy 1989: 42.

Type material. HOLOTYPE – NTM S.11193-005, 38 mm SL male, spawning ponds, Bowstead's barramundi farm, on bend of river NE of Harrison Dam, Adelaide River, R. Lau, 4 October 1993. PARATYPES – NTM S.11193-004, 59(15–44), same data as holotype; NTM S.15800-001, 13(33–47.5), mudflats under Derby jetty, WA, T. Takita, 18–19 July; WAM P.32464.001, 4(33.5–47.5), mudflats under Derby jetty, WA, T. Takita, 18 July 2002; AMS I.43240-001, 3(39.5–46.5), mudflats under Derby jetty, WA, T. Takita, 18 July 2002; NTM S.14467-006, 9(32–42), mud and gravel pools on rockbar at Smith's Landing, East Alligator River, NT, H.K. Larson and G. Lindner, 3 June 1997; NTM S.10426-002, 17(32–41), upstream Buffalo Creek, H.K. Larson and party, 21 April 1982; NTM S.14024-013, 16(33–46), small creek on north side Roper River near Port Roper, H.K. Larson and R.S. Williams, 8 September 1994.

Diagnosis. A slender *Periophthalmus* (body depth at anal fin origin 12.2–14.5% of SL, mean 13.5%), with pelvic fins often heavily pigmented, a submarginal black stripe and basal row of black spots on second dorsal fin; first dorsal fin usually XI, fin rounded to slightly pointed anteriorly, moderate in height, falling well short of second dorsal fin origin when depressed (length 13.0–25.6% of SL); pelvic fins with distinct frenum, united for about half their length, fin tips rounded, fifth ray bifurcated close to base, branching about 9 times; first dorsal fin dark grey to black, with broad white to translucent margin; second dorsal fin pale with broad submarginal black band and row of oval black spots along fin base; anal fin whitish usually with intermittent blackish patches medially; pelvic fins dark grey to blackish dorsally, blackish pigment along fin rays ventrally; second dorsal fin modally I,12; anal fin modally I,11; pectoral rays 12–15; caudal fin with 9–15 branched rays usually in 6/6 pattern, upper and lower 1–3 rays unbranched; lateral scales 71–112; predorsal scales 24–32.

Description. Based on 36 specimens, 28.5–47.5 mm SL.

First dorsal fin XI (IX-XIV); second dorsal fin I,12 (I,11–13); anal fin I,11 (I,10–12); pectoral rays 15 (12–15); caudal fin segmented rays in 9/8 pattern (8/8 to 9/8, nearly always 9/8), with branched rays in 6/7 pattern (5/4 to 8/7, modally 6/6); lateral scales 81 (71–112); TRB 20 (18–27); TRF 20 (20–30); predorsal scales 28 (25–32). Dorsal pterygiophore pattern 3-1311000 (in nine specimens), 3-132100 (in three), 3-13100 (in one), 3-131000 (in two), 3-230100 (in one), 3-132000 (in one); 1–2 pre-anal pterygiophores (modally 1); 1–2 epurals (modally 2) (Table 3).

Body relatively slender; adult size small (Fig. 3), maximum size 47.5 mm SL (mean 39 mm); largest specimens are female (up to 47.5 mm SL; largest male 44.5 mm SL). Head length 25.6–27.9% of SL, head depth slightly greater than head width. First dorsal fin moderately tall, rounded to slightly pointed and triangular in shape; second or third spine usually longest or first three spines subequal; spines falling short of second dorsal fin origin when depressed. Females with shorter and lower first dorsal fin than males, with gap between dorsals 3.9% of SL in holotype, mean 6.2%; distance greater in females (range 3.4–10.5% and a mean of 7.0% in females, range 2.7–8.9% and a mean of 5.2% in males). Second dorsal and anal fins low, rays falling well short of caudal fin base; second dorsal fin base almost equal to caudal peduncle length; distance between posteriomost second

Fig. 3. Holotype of *Periophthalmus murdyi* n. sp., NTM S.11193-005, 38 mm SL male, Adelaide River, NT. Photograph by T. Takita.

dorsal fin ray and caudal fin base 15.8–18.3% of SL (Table 4). Pelvic fins with distinct frenum; fins united for about half their length; fin tips rounded to slightly pointed; fifth ray bifurcated close to base, branching about nine times, fifth ray bases close, not wide-set (Fig. 7). Caudal fin rather narrow (Fig. 8).

Females with short blunt slightly cylindrical genital papilla; papilla in males flattened and usually pointed, usually somewhat elongate.

Table 3. Counts and measurements of specimens of *Periophthalmus murdyi* n. sp.

	Holo.	Mean	Max.	Min.	Mode
First dorsal fin spines	11.0	11.5	14.0	9.0	10.0
Second dorsal fin rays	12.0	12.1	13.0	11.0	12.0
Anal fin rays	11.0	10.9	12.0	10.0	11.0
Pectoral rays right	15.0	13.8	15.0	13.0	14.0
Pectoral rays left	15.0	13.8	15.0	12.0	14.0
Caudal segmented	17.0	16.8	17.0	15.0	17.0
Caudal branched	13.0	11.3	15.0	4.0	12.0
Lateral scales	85.0	81.1	112.0	71.0	75.0
Transverse rows back	20.0	22.0	27.0	18.0	21.0
Transverse rows forward	20.0	24.2	30.0	20.0	24.0
Predorsal scales	28.0	28.2	32.0	25.0	28.0
Standard length	38.0	39.1	47.5	28.5	38.0
Head length	10.0	10.5	13.0	7.5	10.2
Head width	6.8	6.7	8.5	4.9	6.1
Head depth	7.4	6.9	9.3	5.3	6.8
Body depth at anal base	5.1	5.3	6.7	3.5	5.5
Body depth at pelvic base	7.0	6.9	8.8	4.8	6.8
Length before D1	13.3	14.0	17.1	10.2	13.7
D1 base length	7.1	7.3	11.3	3.7	8.1
Distance between dorsals	1.5	2.4	3.9	1.0	2.2
D2 base length	9.0	8.8	11.2	6.4	8.2
Length behind D2	6.5	7.2	8.7	5.0	6.7
Anal base length	7.6	7.4	9.1	5.6	8.0
Caudal peduncle length	7.3	8.2	10.1	6.3	7.6
Caudal peduncle depth	3.3	3.4	4.4	2.4	3.5
Depressed D1	8.1	7.8	11.9	3.7	10.1
Pectoral base height	2.8	2.7	3.5	1.8	2.5
Pectoral length	5.7	6.7	9.1	5.2	6.6
Pelvic length	4.8	4.9	6.1	3.5	4.7
Caudal length	9.1	8.9	10.8	7.0	8.1
First D1 spine	4.4	5.3	9.3	2.5	6.3
Second D1 spine	4.5	5.2	9.0	2.3	4.2
Third D1 spine	4.6	4.8	5.8	3.8	5.8

Coloration of preserved material. Head and body light brown to fawn, paler brown to white ventrally, with 8–10 forwardly-oblique irregular dark brown bars across dorsum (Figs 4–6), bars may be indistinct dorsally and only visible laterally, and usually end on mid-side of body; bar width variable, usually alternating between broad and narrow bars (Fig. 3). Typically, broadest bars cross nape above pectoral base, at rear of first dorsal fin, at anterior half of second dorsal fin, and at rear of second dorsal fin. Head may be rather plain or with dark brown mottling and reticulation, which may form irregular oblique streaks. Some specimens with silvery white spots and small blotches on lower half of head and along side of body. Underside of head and prepelvic area pale brownish to dusky brownish, sometimes with darker brown area over branchiostegal rays; darker pigment may coalesce over isthmus in some specimens.

Table 4. Morphometrics of specimens of *Periophthalmus murdyi* n. sp., expressed as percentage of standard length (SL) or head length (HL).

	Holo.	Mean	Max.	Min.
HL in SL	26.3	26.7	27.9	25.6
HD in HL	68.0	64.2	73.6	58.7
HW in HL	74.0	65.8	74.0	58.8
BD at A base in SL	13.4	13.5	14.5	12.2
BD at P2 base in SL	18.4	17.6	19.5	16.6
Length anterior to D1 in SL	35.0	35.7	37.4	33.8
D1 base length in SL	18.7	18.6	24.3	13.0
Distance between dorsal fins in SL	3.9	6.2	10.5	2.7
D2 base in SL	23.7	22.5	24.7	15.8
Distance from D2 last ray to caudal in SL	17.1	18.3	20.0	15.8
A base in SL	20.0	18.9	21.4	17.4
CPL in SL	19.2	21.0	22.6	19.2
CPD in SL	8.7	8.8	9.4	7.8
Depressed D1 in SL	21.3	19.7	25.6	13.0
Pectoral base in SL	7.4	7.0	7.9	6.2
Pectoral in SL	15.0	17.3	20.8	15.0
Pelvic in SL	12.6	12.4	13.7	11.3
Caudal in SL	23.9	22.8	25.6	20.3
First D1 spine in SL	11.6	13.3	20.0	7.5
Second D1 spine in SL	11.8	13.1	19.4	6.9
Third D1 spine in SL	12.1	12.7	13.4	11.9

First dorsal fin plain greyish to black, often slightly paler proximally, with broad transparent to translucent whitish margin. Second dorsal fin transparent to hyaline, with single broad grey to black stripe placed at two-thirds height of fin and single row of grey to black rounded to oval spots just above fin base, each spot placed on membrane before each fin ray, spots may partly coalesce in some specimens forming an irregular basal stripe. Anal fin variable, either plain translucent, white or whitish with series of short dusky broken streaks parallel to each fin ray; streaks most pronounced posteriorly and in heavily pigmented specimens (e.g. breeding males). Caudal fin plain grey to brown, without distinct spots; pigment most prominent along fin rays. Pectoral fin translucent with narrow lines of brown pigment along fin rays. Pelvic fins whitish dorsally; ventrally with dusky to brown pigment along rays but absent from fin margin; dorsally fins dusky to dark brown with broad unpigmented (whitish) margin and area over fifth rays unpigmented; anterodorsal part of fins darkest.

Coloration of fresh material. Head and body of freshly dead specimens (Figs 4, 5) light greyish to pinkish brown, becoming whitish on underside of head, belly and caudal peduncle; tiny brown to reddish brown spots scattered evenly over head and body, as are pale blue iridescent spots or short vertical lines; four to seven soft grey-brown forwardly-oblique bars (may be incomplete or indistinct) extend along sides from dorsum, two partial grey-brown saddles across predorsal region.

First dorsal fin reddish, with broad blackish submarginal band and white to pinkish broad fin margin. Second dorsal fin whitish to pinkish white with broad blackish submarginal band (broader in males than in females) and whitish margin; basal third to half of fin pale dusky with short greyish to blackish streak or oval spot on membrane adjacent to each fin ray, dark spots becoming more diffuse posteriorly. Anal fin whitish in females, dusky to charcoal grey in males; ray tips yellowish to pinkish yellow. Caudal fin membranes translucent, fin rays pinkish brown to pale greyish brown on dorsal half of fin, dusky grey to dark grey on ventral half; ray tips on ventral half of fin fleshy pink to yellowish pink; about 10 irregular vertical rows of dusky grey spots, coalescing with background colour on ventral half of fin. Pectoral fins translucent pinkish orange to greyish orange. Pelvic fins in female greyish orange, duskier dorsally; in males, pelvic fins grey to charcoal grey with pinkish orange to greyish orange frenum and fin ray tips.

Live specimens from the Roper River were noted only as being 'Fawn with fine sky blue spots over sides of head and body' (H. Larson, field notes). Figure 6 shows these fine spots on a living fish from Derby, WA.

Distribution. North-western Australia; known from Derby, WA. to Roper River, NT. The ecology of this species will be discussed by Takita (in prep.).

Remarks. This species resembles *P. modestus* Cantor, 1842, which is known from southern China, Korea and southern Japan. It can be separated from *P. modestus* by the placement of the basal row of dusky spots in the second dorsal fin (spots on membrane in *P. murdyi* and spots on fin rays themselves in *P. modestus*); darkly pigmented pelvic fins, a narrower and more pointed caudal fin (caudal fin in *P. modestus* is broader and more rounded, especially in large adults; Fig. 8A–C), slightly lower lateral scale count (71–112 with mean of 81, versus 75–100 with mean of 85 in *P. modestus*), slightly lower dorsal spine count (IX–XIV, mean XI, in *P. murdyi* versus X–XVII, mean XIII, in *P. modestus*) and smaller size (the largest *P. murdyi* we examined was 47.5 mm SL, while the largest recorded *P. modestus* is 80.2 mm SL (Lee *et al.*

Fig. 4. Freshly dead male *Periophthalmus murdyi* n. sp., from Derby, WA. Photograph by T. Takita.

Fig. 5. Freshly dead female *Periophthalmus murdyi* n. sp., from Derby, WA. Photograph by T. Takita.

Fig. 6. Live *Periophthalmus murdyi* n. sp., on mud bank in Derby harbour, WA. Photograph by T. Takita.

1995). The dorsal pterygiophore patterns differ (although are variable) between the two, e.g. Murdy reported seven specimens of *P. modestus* with 3-131100 pattern, while only one *P. murdyi* had this pattern (nine had 3-1311000). Additionally, three specimens of *P. modestus* reported by Murdy (1988) and four specimens examined by us, had the pattern 3-1301000 (this pattern also reported for *P. modestus* by Lee *et al.* 1995), which was not observed in any of the 17 specimens of *P. murdyi* in which the pterygiophore insertion pattern could be easily seen (it is difficult to take successful radiographs of *Periophthalmus* specimens, due to their stiff pectoral fin base and fin). *Periophthalmus murdyi* co-occurs with *P. novaegnineaensis*, but differs from that species by its high lateral scale count (71–112 versus only 50–65 in *P. novaeguineaensis*) and single dark stripe and row of basal dark spots on second dorsal fin (versus two black stripes and basal row of dark spots on second dorsal fin in *P. novaeguineaensis*).

Of the specimens reported as *P. novaeguineaensis* by Murdy (1989), one lot of 17 specimens is *P. murdyi* (NTM S.10426-002).

Etymology. Named for our goby colleague Edward Murdy, in appreciation of his considerable work on mudskipper taxonomy and relationships.

Periophthalmus novaeguineaensis Eggert, 1935

(Figs 7E,F, 9; Tables 5, 6)

Material examined. NTM S.10418-004, 13(32–71), flat mangrove area at Camerons Beach, Shoal Bay, NT, HL 82-5, H. Larson, 26 February 1982; NTM S.10410-003, 4(28–30), upstream from Spot On Marine, Ludmilla Creek, Darwin, NT, HL 81-51, H. and J. Larson, 29 December 1981; NTM S.13475-001, 1(70), mangroves to left of Channel Island bridge, Darwin Harbour, NT, site 3, M. Burke, 3 July 1991; NTM S.10421-002, 1(59.5), mud banks on small peninsula near Elizabeth River mouth, Darwin Harbour, NT, HL 82-8, H. Larson and R. Hanley, 29 March 1982; NTM S.13496-003, 1(57), mangroves by Channel Island bridge, Darwin Harbour, NT, site 3, M. Burke, 18 March 1992; NTM S.15492-002, 2(39-65), mangroves at Charles Darwin National Park, Darwin Harbour, NT, K. Metcalfe, August 2001; NTM S.14637-032, 5(23-64), mud and gravel substrate over rocky reef at south end Field Island, NT, RW 98-7, R. Williams and party, 27 May 1998.

Diagnosis. The diagnosis and description presented is based only on available northern Australia material, as it was not possible to re-examine (to verify their identity) all the specimens that Murdy used.

A stocky *Periophthalmus* (body depth at anal fin origin 11.8–19.0% of SL, mean 15.6%), nearly always with VIII first dorsal fin spines; first dorsal fin broadly rounded; gap between dorsal fins 3.0–8.1% of SL; pelvic fins united for half their length, distinct fraenum present, posterior tips of fins rounded, fifth pelvic ray branching about 5 times, first branch point about halfway up ray; first dorsal fin entirely plain grey to blackish in preservative, often only with tips whitish; second dorsal fin with two black bands, one submarginal and one medial, and a basal row of black spots or blotches; no markings on anal fin; pelvic fins whitish, sometimes with a few brownish speckles along fin rays on dorsal surface of fin; when alive, warm brown and dark orange spots on side of head, becoming fewer on side of body, spots persist in preservative; second dorsal and anal fins I,12; pectoral rays modally

Fig. 7. Pelvic fin structure of several species of *Periophthalmus*, showing differences in fin shape and amount of membrane joining fifth pelvic fin rays. **A**, *P. darwini* n. sp., ventral view of pelvic fins; **B**, *P. darwini* n. sp., ventral view of excised pelvic fins, showing ray branching; **C**, *P. murdyi* n. sp., ventral view of pelvic fins; **D**, *P. murdyi* n. sp., ventral view of excised pelvic fins, showing ray branching; **E**, *P. novaegnineaensis*, ventral view of pelvic fins; **F**, *P. novaegnineaensis*, ventral view of excised pelvic fins, showing ray branching.

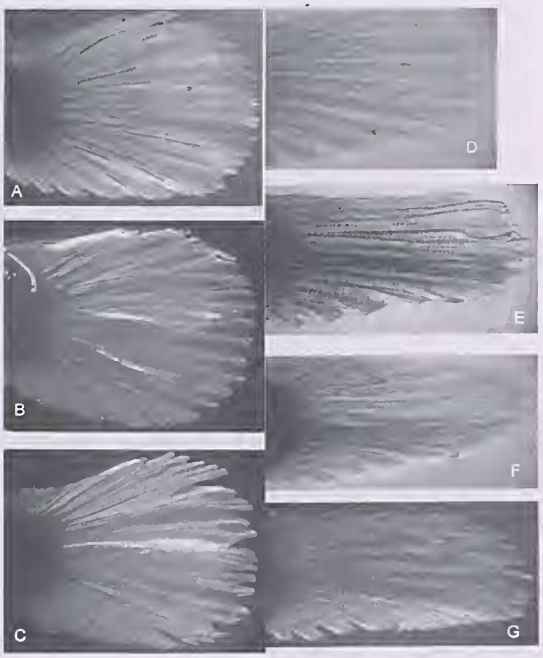

Fig 8. Caudal fins of *Periophthalmus modestus* (**A-C**) and *P. murdyi* n. sp. (**D-G**), showing differences in shape.

14; caudal fin with 11–15 branched rays, typically in 7/6 pattern; lateral scales 50–65; predorsal scales 23–32.

Description. Based on 25 specimens, 31–70.5 mm SL.

First dorsal fin VII-IX, usually VIII; second dorsal fin I,11–12, usually I,12; anal fin I,10–12, usually I,12; pectoral rays 13–15, usually 14; caudal fin segmented rays 17, in 9/8 pattern, with branched rays in 6/5 to 7/8 pattern; lateral scales 50-65, mean 57; TRB 16–22; TRF 18–25; predorsal scales 23–32, mean 27 (Table 5).

Robust in appearance; reaching moderately large size, up to 70.5 mm SL (mean length 49 mm). Head length 22.4–35.6% of SL; head depth always greater than head width. First dorsal fin tall, broad and rounded, spines falling short of second dorsal fin origin; first or second spine usually longest. Short gap between dorsal fins, mean 4.9% of SL. Second dorsal taller than anal fin, but always lower than first dorsal, posteriormost rays of second dorsal reach to first few upper procurrent rays of caudal fin when depressed; distance between posteriomost second dorsal fin ray and caudal fin base 10.7–20.0% of SL (Table 6). Pelvic fins united for about half their length, distinct frenum present, posterior tips of fins rounded, fourth and fifth pelvic rays about equal in length; fifth ray branching about five times with first branch point about halfway up ray. Males with larger first dorsal fins than females and a shorter gap between dorsal fins. Females with short blunt cylindrical genital papilla; papilla in males flattened, rounded to pointed, usually somewhat elongate.

Table 5. Counts and measurements of specimens of *Periophthalmus novaeguineaensis*.

	Mean	Max.	Min.	Mode
First dorsal fin spines	8.1	9.0	7.0	8.0
Second dorsal fin rays	12.0	12.0	11.0	12.0
Anal fin rays	11.9	12.0	10.0	12.0
Pectoral rays right	13.9	14.0	13.0	14.0
Pectoral rays left	13.9	15.0	13.0	14.0
Caudal segmented	16.6	17.0	15.0	17.0
Caudal branched	12.6	15.0	11.0	13.0
Lateral scales	57.3	65.0	50.0	57.0
Transverse rows back	19.2	22.0	16.0	20.0
Transverse rows forward	20.4	25.0	18.0	20.0
Predorsal scales	26.9	32.0	23.0	26.0
Standard length	49.2	70.5	31.0	34.5
Head length	14.0	20.0	9.3	13.2
Head width	8.9	12.7	5.8	8.4
Head depth	10.1	15.6	7.2	7.6
Body depth at anal base	7.6	10.4	4.8	6.6
Body depth at pelvic base	9.5	14.3	6.2	8.4
Length before D1	17.8	25.9	11.1	13.3
D1 base length	9.4	13.0	4.9	11.5
Distance between dorsals	2.3	3.9	1.3	2.4
D2 base length	12.0	18.4	7.1	14.9
Length behind D2	7.7	12.8	4.8	6.8
Anal base length	10.0	13.6	6.1	13.4
Caudal peduncle length	8.9	13.2	5.3	8.8
Caudal peduncle depth	5.0	7.0	3.4	3.7
Depressed D1	10.4	15.1	4.9	13.1
Pectoral base height	3.9	6.1	2.5	5.2
Pectoral length	9.7	14.9	6.2	8.0
Pelvic length	5.8	8.3	4.5	4.9
Caudal length	12.4	18.2	8.5	9.3
First D1 spine	8.2	12.7	3.3	4.5
Second D1 spine	8.2	12.8	3.4	-
Third D1 spine	7.7	12.3	3.7	8.4

Coloration of preserved material. Figure 41 and plate 2F in Murdy (1989) show typical coloration; especially the second dorsal fin pattern in plate 2F.

Head and body light brown, usually with five dark brown saddle-like blotches across dorsum: first at first dorsal fin origin, second at rear end of first dorsal, third at centre of second dorsal fin base, fourth at rear end of second dorsal fin and fifth across middle of caudal peduncle; blotches extend ventrally to mid-lateral line or a little further, may branch ventrally; blotches often diffuse or indiscernible. Dark brown rounded spots scattered over side of head and body; smaller spots also present on head. Ventral half of body often paler, usually with short whitish vertical lines along lower side of body; some specimens with small white or silvery white spots on side of body, on opercle and sometimes on pectoral fin base.

First dorsal fin grey to blackish, may become darker distally; fin spines and narrow margin of fin unpigmented. Second dorsal fin with two black bands, with melanophores on rays where bands cross them, one band submarginal and one medial, and a basal broken black line or row of black blotches, width of

Table 6. Morphometrics of specimens of *Periophthalmus novaeguineaensis*, expressed as percentage of standard length (SL) or head length (HL).

	Mean	Max.	Min
HL in SL	28.6	35.6	22.4
HD in HL	63.9	70.1	56.0
HW in HL	72.9	80.5	58.3
BD at A base in SL	15.6	19.0	11.8
BD at P2 base in SL	19.2	24.4	14.2
Length anterior to D1 in SL	36.4	41.5	28.5
D1 base length in SL	19.0	22.3	15.5
Distance between dorsal fins in SL	4.9	8.1	3.0
D2 base in SL	24.4	30.5	17.5
Distance from D2 last ray to caudal in SL	15.6	20.0	10.7
A base in SL	20.5	25.9	14.3
CPL in SL	18.3	22.5	13.3
CPD in SL	10.3	12.4	7.6
Depressed D1 in SL	20.6	28.8	15.7
Pectoral base in SL	8.0	9.5	5.8
Pectoral in SL	19.7	24.6	16.0
Pelvic in SL	12.0	14.8	8.5
Caudal in SL	25.3	30.5	16.6
First D1 spine in SL	16.3	22.5	10.6
Second D1 spine in SL	16.1	20.8	11.0
Third D1 spine in SL	15.8	19.4	11.9

transparent interspaces about equal to width of the two black bands. Anal fin plain whitish or translucent, occasionally a few melanophores present. Caudal fin plain dusky, often with scattered dusky spots that may form irregular rows. Pectoral fin dusky, darker along edges of rays, tips unpigmented. Pelvic fins whitish, sometimes with a few brownish speckles along fin rays on dorsal surface of fin.

Coloration of fresh material. Coloration of a freshly dead specimen from Darwin is shown in Figure 9. Live specimens have a yellow to pale yellow anal fin, reddish first dorsal fin and dark orange spots along the lower half of the head and body.

Distribution. Known from West Papua (Merauke), Papua New Guinea (Fly River) and north-western Australia (Port Hedland to Townsville).

Remarks. We were able to examine notes on the lectotype of *Periophthalmus novaeguineaensis* (ZMA 112.945), made by Ed Murdy, as the specimen was not available for study.

Fig. 9. Freshly dead specimen of *Periophthalmus novaeguineaensis*, from Ludmilla Creek, Darwin, NT. Photograph by T. Takita.

The holotype of *Periophthalmus expeditionium* Whitley, 1953 (AMS I.6195), synonymised with *P. novaeguineaeusis* by Murdy (1989), was examined during this study to determine if it shared characters with *P. darwini* or *P. murdyi*. It appears to be more similar to *P. novaeguineaensis* in body proportions and form of the pelvic fin and its rays, but differs from that species in having XI first dorsal spines (versus VIII, rarely IX) and more lateral scales (78, versus 50-65). We recognise it here as a possible separate species, which should be compared with other specimens from the Gulf of Carpentaria (its type locality is Karumba). Whitley also had two small paratypes from the Forrest River area, WA, of which one of these had a "minute spinous dorsal fin" (Whitley1953). This specimen could be *P. darwini*.

The 41 specimens from Gunn Point, NT (NTM S.10694-001), identified by Murdy (1989) as *P. novaeguineaensis* were found to consist of 14 specimens of *P. darwini* and 27 specimens of an unidentified species resembling *P. novaeguineaensis* but differing in having many fine dark brown spots (not scattered large dark brown spots) on the head and body and in first dorsal fin coloration. Identification of this species awaits collection of additional material.

KEY TO SPECIES

The two new species, which have a visible pelvic frenum, will fall out in Murdy's key (1989) somewhere near couplets 6 and 7 (*P. novaeguineaensis, P. waltoui* Koumans, 1941, and *P. modestus*), but are clearly none of these species. They also differ from the recently described *P. spilotus* Murdy and Takita, 1999, *P. magnuspinnatus* Lee, Choi and Ryu, 1995 and *P. walailakae* Darumas and Tantichodok, 2002, which do not appear in Murdy (1998). We thus have included a revised key to all *Periophthalmus* species, based on Murdy's 1989 key (*n.b.* specimens of *P. magnuspinnatus* were not available for study).

Key to *Periophthalmus* species (modified from Murdy 1989)

1a. Frenum uniting pelvic spines either prominent or vestigial, if vestigial, visible without magnification 2

1b. No pelvic frenum or, if present, visible only with magnification 13

2a. Innermost pelvic fin rays of both fins joined by membrane for entire length to form a rounded disk 3

2b. Innermost pelvic fin rays of both fins not joined by membrane for entire length, no disk present. 5

3a. D2 and A rays greater than 1,10 and 1,9, respectively; distal margin of D1 straight..... 4

3b. D2 rays I,10; A rays I,8-10; distal margin of D1 rounded (Thailand to Singapore) ....*P. walailakae* Darumas and Tantichodok, 2002

4a. When alive, whitish to bluish-white spots present on head and body; D2 with I,13, rarely I,14, rays; A with I,12-14 rays (Sumatra, peninsular Malaysia) .... *P. spilotus* Murdy and Takita, 1999

4b. When alive, orange spots present on head and body; D2 with I,11-12 rays; A with I,10-12 rays (India to Java) .... *P. chrysospilos* Bleeker, 1852

5a. Spinous dorsal fin with numerous white or black spots 6

5b. Spinous dorsal fin with few or no spots 8

6a. Pelvic frenum prominent; Dl IX-XI, usually IX-X; longitudinal scale count typically fewer than 70 7

6b. Pelvic frenum vestigial; Dl XI-XV; longitudinal scale count 66-86, averaging 75 (east Africa to western Pacific) ..... *P. kalolo* Lesson, 1830

7a. Dl with black spots (orange when live), ventral margin of gill cover often blackish; longitudinal scale count 61-76; D2 rays I,12-13; A rays I,11-13 (India to Philippines) .... *P. novemradiatus* (Hamilton, 1822)

7b. Dl with many small white spots, ventral margin of gill cover same colour as rest of head; longitudinal scale count 47-61, usually fewer than 60; D2 rays I, 10-11; A rays I,10-11 (Indonesia, Philippines) ..... *P. malaccensis* Eggert, 1935

8a. D1 fin greatly reduced in both sexes, with wide gap (always greater than D1 base) between rear of D1 and D2 origin; D1 with IV-VI spines, usually V (north-western Australia) .... *P. darwini* n. sp.

8b. D1 fin may be small in females, but gap between dorsals always narrower than D1 base; D1 with V-XVII spines, typically IX or more 9

9a. Longitudinal scale count 90-120; D2 I,12-13; D1 mostly plain grey with narrow black margin or row of small black spots (Arabian Gulf to Pakistan) ..... *P. waltoni* Koumans, 1941

9b. Longitudinal scale count usually fewer than 90; D2 usually I,12-13 or fewer; D1 plain blackish or with white margin, with or without inframarginal dark stripe 10

10a. Longitudinal scale count usually more than 80; in preserved adults, only 1 submarginal dusky stripe on D2 (either black or brown), may also be row of dark spots close to base of fin 11

10b. Longitudinal scale count 50-65; in preserved adults, 2 solid black stripes on D2 as well as a partial row of dark spots along base of fin (southern New Guinea to northern Australia) .... *P. novaeguineaensis* Eggert, 1935

11a. D1 large in adults, height greater than body depth, margin convex; prominent submarginal black band in D1 (Korea) .... *P. magnuspinnatus* Lee, Choi and Ryu, 1995

11b. D1 low to moderate, height less than or subequal to body depth; submarginal dark band in D1 variable in intensity 12

12a. Round to oval dusky spots, in row along base of second dorsal fin, placed on membrane between rays; broad dark stripe on second dorsal fin located at 2/3 of fin height; caudal fin rather narrow and pointed posteriorly (northern Australia) .... *P. murdyi* n. sp.

12b. Round dusky spots, in row along base of second dorsal fin, placed on fin rays; broad dark stripe on second dorsal fin located at mid-point of fin; caudal fin broad and rounded posteriorly (China to Japan) ..... *P. modestus* Cantor, 1842

13a. Dl and D2 contiguous in adult males, Dl greatly reduced in females, barely perceptible in some; D2 lacking stripes (Papua New Guinea and Australia) ..... *P. weberi* Eggert, 1935

13b. Dl and D2 not contiguous but may be close together in males and females, Dl not reduced in females; D2 with single dusky stripe 14

14a. Dl with white or black spots; longitudinal scale count usually fewer than 90 15

14b. Dl lacking spots or occasionally with a few white spots posteriorly; longitudinal scale count usually more than 90 (tropical west Africa) .... *P. barbarus* (Linnaeus, 1766)

15a. Dl rounded with prominent black spot posteriorly; Dl usually X or fewer (Malaysia, Indonesia, Australia, Philippines) .... *P. gracilis* Eggert, 1935

15b. Dl pointed and lacking black spot posteriorly; Dl usually more than X 16

16a. Dl with prominent black stripe inframarginally; ventral peritoneum densely black; longitudinal scale count usually 75 or more (western Indian Ocean to Oceania) .... *P. argentilineatus* Valenciennes, 1837

16b. Dl with light-brown stripe inframarginally; ventral peritoneum lightly pigmented medially; longitudinal scale count usually fewer than 75 (Andaman Islands, Thailand, Indonesia, Australia, Philippines) ..... *P. minutus* Eggert, 1935

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